REPORT DOCUMENTATION PAGE

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Department of Defense, Executive Services and Communications Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
					19b. TELEPHONE NUMBER *(Include area code)*

URGENT

14-1231-3374

PUBLICATION OR PRESENTATION RELEASE REQUEST

Pub Key: 3414   NRLINST 5600.2

Ref: (a) NRL Instruction 5600.2
(b) NRL Instruction 5510.40D

End: (1) Two copies of subject paper
(or abstract)

( ) Abstract only, published
( ) Book
( ) Conference Proceedings
(refereed)
( ) Invited speaker
( ) Journal article (refereed)
( ) Oral Presentation, published
(X) Other, explain

( ) Abstract only, not published
( ) Book chapter
( ) Conference Proceedings
(not refereed)
( ) Multimedia report
( ) Journal article (not refereed)
( ) Oral Presentation, not published

STRN NRL/PU/7320-14-2346
Route Sheet No. 7320/
Job Order No. 73-6764-04-5
Classification X , U C
Sponsor ONR BASE
approval obtained ___ yes X no

Title of Paper or Presentation
Monitoring maritime conditions with unmanned systems during Trident Warrior '13

Author(s) Name(s) (First,MI,Last), Code, Affiliation if not NRL

Charlie N. Barron 7321 Emanuel Coelho University of New Orleans Kenneth Grembowicz NAVO Edward Holmberg University of New Orleans
Sherwin D. Ladner 7331 Andrea Mask NAVO Germana Peggion UNO Andrew J Quaid 7332 Lucy F. Smedstad 7321

It is intended to offer this paper to the _____
(Name of Conference)

_____
(Date, Place and Classification of Conference)

and/or for publication in   2014 NRL Review Article, Unclassified
(Name and Classification of Publication)   (Name of Publisher)

After presentation or publication, pertinent publication/presentation data will be entered in the publications data base, in accordance with reference (a).
It is the opinion of the author that the subject paper (is ___) (is not X) classified, in accordance with reference (b).
This paper does not violate any disclosure of trade secrets or suggestions of outside individuals or concerns which have been communicated to the Laboratory in confidence. This paper (does ___) (does not X) contain any militarily critical technology.
This subject paper (has ___) (has never X) been incorporated in an official NRL Report.

Charlie N. Barron, 7321
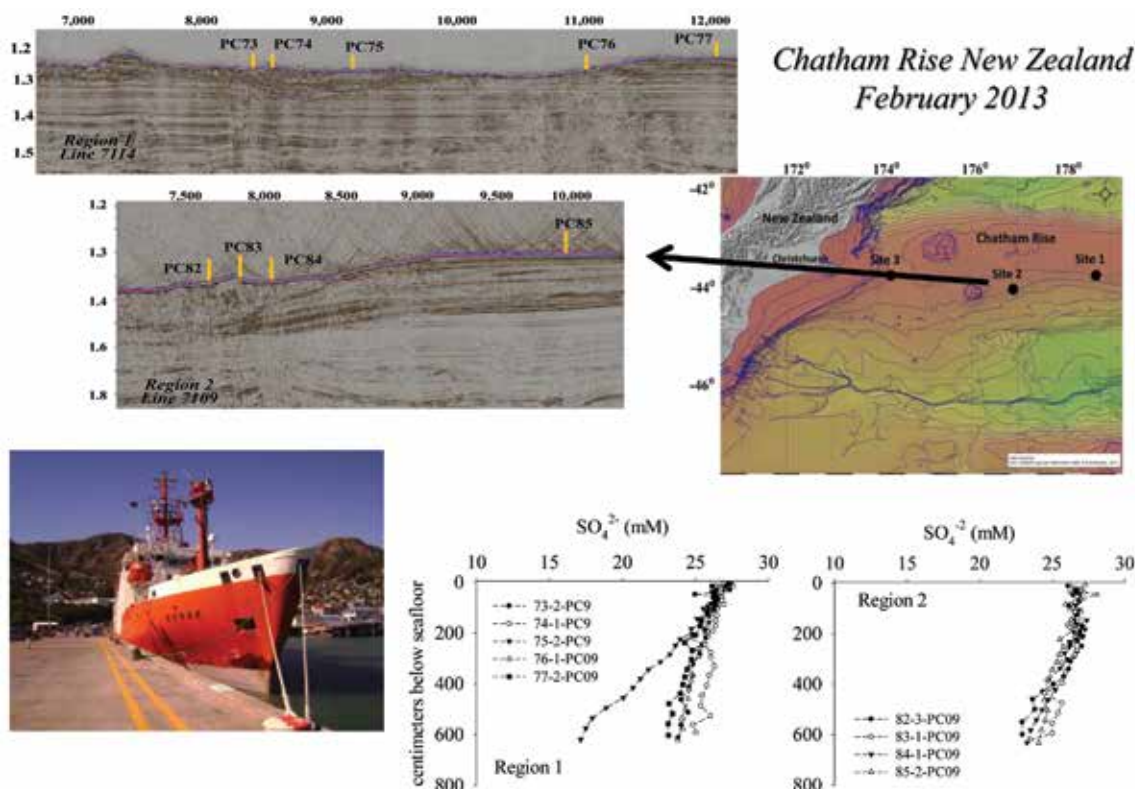Name and Code (Principal Author)   (Signature)

CODE	SIGNATURE	DATE	COMMENTS
Author(s) Charlie Barron, 7321		10-1-14	Need by 14 Oct 2014
			Publicly accessible sources used for this publication
			This is a Final Security Review. Any changes made in the document, after approved by Code 1231, nullify the Security Review.
Section Head			
Branch Head Gregg A. Jacobs, 7320		10-1-14	
Division Head Ruth H. Preller, 7300		10/3/14	1. Release of this paper is approved. 2. To the best knowledge of this Division, the subject matter of this paper (has ___) (has never X) been classified.
Security, Code 1231		10/3/14	1. Paper or abstract was released. 2. A copy is filed in this office.
Office of Counsel,Code 1008.3	Kathy Chapman	10/14/14	
ADOR/Director NCST E. R. Franchi, 7000			
Public Affairs (Unclassified/ Unlimited Only), Code 7030.4	Shannon Mensi	10-14-14	
Division, Code			
Author, Code			

3 OCT '14 PM 2:2

FIGURE 4
A comparison of geochemical and seismic data from a 2013 expedition aboard the RV *Sonne*, off the coast of New Zealand across the Chatham Rise. Two seismic lines were studied at this location to evaluate the vertical methane flux. Here we present sulfate data related to the spatial variation in sediment methane concentrations. These sulfate profiles show there was no vertical methane flux at any location.

(almost all methane) entering the ocean–atmosphere system, but also in many cases to determine the origin and history of the carbon in that gas. The seismic data allow us to constrain the possible fluid pathways on scales of meters (high-resolution systems like DTAGS) to hundreds of kilometers for larger surface-towed airgun systems. The successful marriage of these two disciplines continues to be an effective means of quantifying the dynamics of gas hydrate in ocean sediments.

[Sponsored by ONR]

References
[1] R.B. Coffin, L. Hamdan, R. Plummer, J. Smith, J. Gardner, and W.T. Wood, "Analysis of Methane and Sulfate Flux in Methane Charged Sediments from the Mississippi Canyon, Gulf of Mexico," *Marine Petroleum and Geology* **25**, 977–987 (2008).
[2] R.B. Coffin, L. Hamdan, J.P. Smith, R. Plummer, L. Millholland, and R. Larson, "Spatial Variation in Shallow Sediment Methane Source and Cycling along the Alaskan Beaufort Sea," *Marine Petroleum and Geology* **45**, 186–197 (2013).
[3] W.S. Borowski, C.K. Paull, and W. Ussler III, "Marine Porewater Sulfate Profiles Indicate In Situ Methane Flux from Underlying Gas Hydrate," *Geol.* **24**, 655–658 (1996).
[4] W.S. Borowski, C.K. Paull, and W. Ussler III, "Global and Local Variations of Interstitial Sulfate Gradients in the Deep-Water, Continental Margin Sediments: Sensitivity to Underlying Methane and Gas Hydrates," *Mar. Geol.* **159**, 131–154 (1999).
[5] W.T. Wood and W.Y. Jung, "Modeling the Extent of the Earth's Methane Hydrate Cryosphere," Proceedings of the 6th International Conference on Gas Hydrates (ICGH 2008), Vancouver, British Columbia, Canada, July 6–10, 2008.
[6] I.A. Pecher, R. Coffin, S.A. Henrys, and GNS Science (NZ), and CHARMNZ Working Group, *Tangaroa TAN0607 Cruise Report: Gas Hydrate Exploration on the East Coast, North Island, New Zealand*, GNS Science Report 2007/29 (Lower Hutt, NZ, 2007).

♦

Monitoring Maritime Conditions with Unmanned Systems During Trident Warrior 2013

C.N. Barron,[1] S.D. Ladner,[1] A.J. Quaid,[1] L.F. Smedstad,[1] K.P. Grembowicz,[2] A. Mask,[2] E.M. Coehlo,[3] E.A. Holmberg,[3] and G. Peggion[3]
[1]Oceanography Division
*[2]Naval Oceanographic Office*
[3]University of New Orleans

Introduction: Before predicting future conditions in the maritime environment, we must sense what the

ocean is doing now. Humans perceive the environment through our senses; comparable perception is also becoming available in autonomous observing platforms. These can feel the warmth of the ocean, taste its saltiness, and see and hear changes in light and sound. Ocean forecasts are improved through the assimilation of these data; our challenge is efficiently obtaining observations and using them in ways that have the greatest impact. NRL researchers teamed with other Navy and academic institutions to address this challenge under the aegis of July's Trident Warrior 2013 (TW13) exercise off the Virginia shore. TW13 hosted deployments of two types of unmanned ocean observing platforms: undersea ocean gliders (Slocum and Spray models) to see, feel, and taste visibility, temperature, and salinity; and surface wave gliders (Sensor Hosting Autonomous Remote Craft or SHARC model) that emit sounds and listen for reflected changes in response to ocean currents. Experiments tested how to guide, adapt, and use observations from these unmanned underwater (UUV) and surface (USV) vehicles. The observations were supplemented with traditional in situ and satellite measurements for assimilation into real-time forecasts of the maritime environment relevant for antisubmarine and mine warfare (ASW/MIW).

Exercise: Trident Warrior is an annual exercise coordinated by the U.S. Fleet Forces Command that provides an operational Fleet environment to assess the impact of new tactics and technology on warfighter needs. The experiments in TW13 were conducted with the cooperation of several ships and aircraft 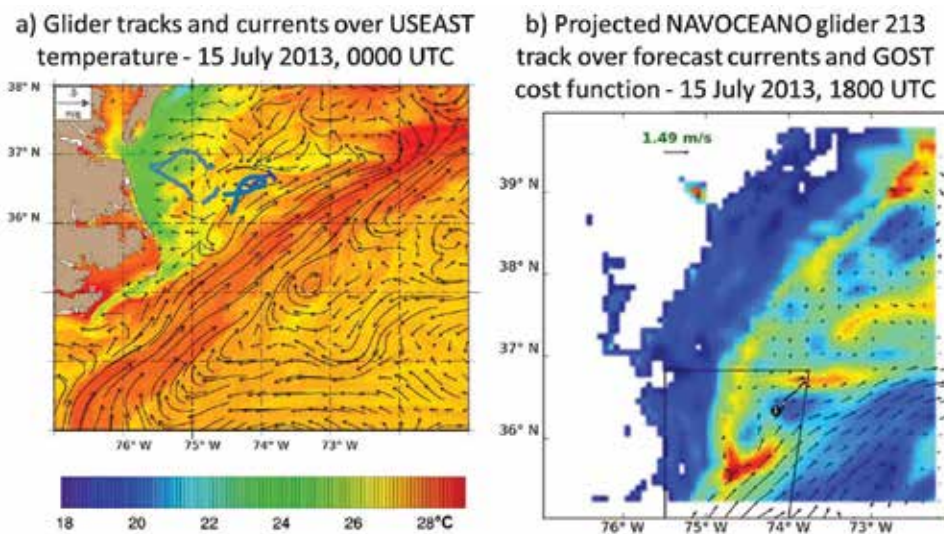from various participating Navy and Air Force commands, in and around the waters east of Virginia and Maryland during July 13 through 18. Researchers from NRL's Oceanography Division joined with contributors from other NRL, Navy, and university groups in an effort coordinated by the Office of Naval Research (ONR) to demonstrate the effectiveness of unmanned observing systems for characterizing the ocean environment within the framework and constraints of a Fleet exercise.

Gliders: Figure 5(a) shows NRL personnel deploying one of the 10 profiling gliders released and recovered from the R/V *Knorr* during the exercise. Data from the two NRL and two Naval Oceanographic Office (NAVOCEANO) gliders were transmitted to Stennis Space Center, processed using the Local Automated Glider Editing Routine (LAGER), and displayed in the NRLSSC real-time display laboratory. Oregon State University controlled and provided data from the six remaining ocean gliders. Four SHARC gliders from UC-San Diego Scripps Institution of Oceanography were also deployed; these provided Acoustic Doppler Current Profiler (ADCP) 3D measurements of the ocean currents as well as measurements of the surface meteorology. Figure 5(b) shows a schematic representation of one wave glider and two ocean gliders superimposed on the real-time forecast of ocean temperature. Glider location tracks (Fig. 6(a)) were updated in real time for the duration of the exercise. In addition to the standard measurements of temperature and salinity, the NRL gliders included bio-optical observation packages with measurements of chlorophyll-a, colored dissolved organic matter (CDOM), beam attenuation coefficient at 660 nm, and backscatter coefficient at 532 nm. Cross
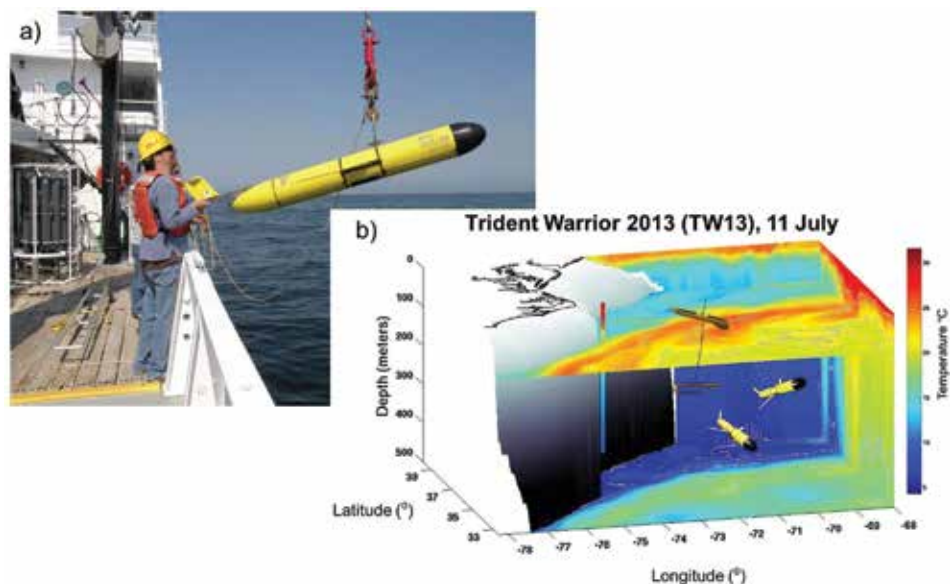
FIGURE 5
(a) NRL personnel deploy a profiling Slocum ocean glider. (b) Two ocean gliders and one SHARC are superimposed on a 3D TW13 ocean temperature forecast valid at 00:00 UTC 11 July 2013.

a) Glider tracks and currents over USEAST temperature - 15 July 2013, 0000 UTC

b) Projected NAVOCEANO glider 213 track over forecast currents and GOST cost function - 15 July 2013, 1800 UTC
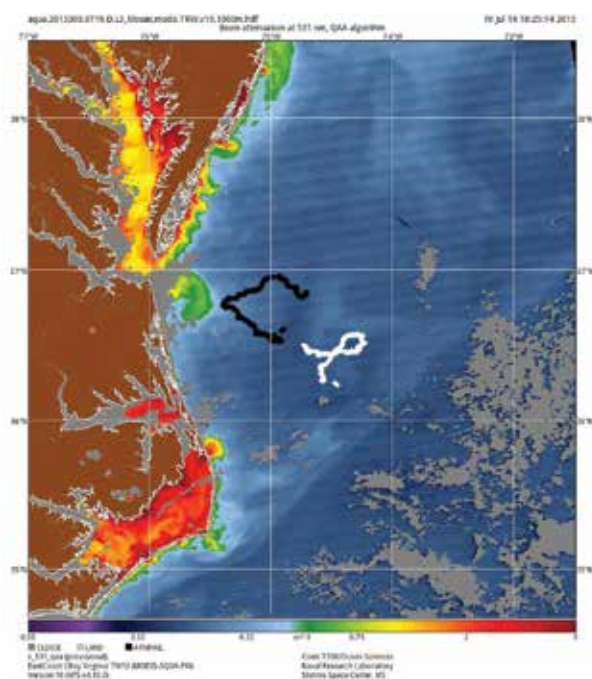
FIGURE 6
(a) NRL and NAVOCEANO gliders focus on optical properties in the inshore region and temperature and salinity for acoustics in the offshore. (b) GOST projects a path for NAVOCEANO glider that is optimized according to the mission-dependent cost function, identifying high-value samples in red. The polygon informs GOST of the waterspace management mandated for the exercise, restricting the gliders to remain south of the main shipping lanes into Chesapeake Bay.

sections of the data received and processed by NRLSSC were on display in real time along with corresponding satellite data and ocean model outputs and products from the region.

GOST: The Glider Observation Strategies (GOST) system developed by NRL identifies glider paths that are likely to cover times and locations with the most impact on assimilative ocean forecasts in the operational area while avoiding areas restricted by waterspace management or challenging operating conditions.[1] GOST uses the forecasts to identify efficient paths through the shifting currents and targets areas where predictions of sound speed or other conditions are uncertain or changing in ways that influence warfighter decisions. During TW13, GOST ran on NAVOCEANO's operational systems and implemented communication links between the ocean modeling and glider operations groups, using model forecasts to project glider paths anticipated to be best suited for the mission and providing this as guidance for the glider pilots (Fig. 6(b)). A new GOST rendezvous option was demonstrated, identifying glider trajectories that maintain high observation value while enabling timely recovery by the R/V *Knorr*.

Optical Forecasts: Additionally, some of the optical and physical ocean data from the gliders are combined with satellite-derived surface optical properties (Fig. 7) and physical models to tune coefficients in a 3D optical model.[2] The Tactical Ocean Data System

(TODS) 3D Optical Generator (3DOG) provides optical parameters in a 3D volume at 1 km grid spacing. These data are combined with ocean current forecasts to feed BioCast, a system to solve for the three-dimensional advection-diffusion-reaction of dissolved or

FIGURE 7
Trajectories of NRL's gliders superimposed on a satellite image processed to estimate beam attenuation at 531 nm. The satellite and glider data are combined in TODS to predict 3D optical parameters and are forecast using RELO-NCOM.

particulate tracers in aquatic environments and forecast changing optical properties out to 24 hours.

References

[1] L.F. Smedstad, K.D. Heaney, G. Peggion, C.N. Barron, and E. Coelho, "Validation Test Report for a Genetic Algorithm in the Glider Observation STrategies (GOST 1.0) Project: Sensitivity Studies," NRL/MR/7320--12-9361, Naval Research Laboratory, Stennis Space Center, MS (2012).

[2] S.D. Ladner, R. Arnone, J. Jolliff, B. Casey, and K. Matulewski, "Forecasting the Ocean Optical Environment in Support of Navy Mine Warfare Operations," *Proceedings of SPIE* **8372**, 83720Z-1, doi: 10.1117/12.920784 (2012).

[3] C.N. Barron, A.B. Kara, P.J. Martin, R.C. Rhodes, and L.F. Smedstad, "Formulation, Implementation and Examination of Vertical Coordinate Choices in the Global Navy Coastal Ocean Model (NCOM)," *Ocean Modelling* **11**(3–4), 347–375, doi:10.1016/j.ocemod.2005.01.004 (2006).

♦

Probing the World's Greatest Source of Variability — Madden Julian Oscillation

M. Flatau,[1] S. Chen,[1] T. Jensen,[2] T. Shinoda,[2] J. Cummings,[2] and P. May[3]
[1]Marine Meteorology Division
[2]Oceanography Division
[3]Computer Sciences Corporation, Monterey, CA

Introduction: The Madden–Julian Oscillation (MJO), named after Roland Madden and Paul Julian, who first described this phenomenon, is a primary mode of atmosphere/ocean variability. The MJO consists of a large, planetary-scale convective anomaly propagating eastward along the Equator over the Indo Pacific warm pool with a phase speed of about 5 to 8 m/s. It influences the atmosphere and ocean on various temporal and spatial scales — from tropical cyclones through monsoons and El Niño in the tropics, to mid-latitude, and even polar, atmosphere, and ocean circulation patterns. The effects of this tropical phenomenon can be observed as far away as ocean current anomalies in the Drake Passage.

MJO behavior depends on multiscale interactions between the global circulation and local convective patterns, as well as feedback between the atmosphere and the ocean. The MJO "cycle" consists of the dry (suppressed) phase, in which clear skies and large insolation allow for heating of the upper ocean and energy is accumulated in the atmosphere/ocean system, and the active phase, in which the energy is released in the form of atmospheric convection (precipitation). A synthesis of the MJO based on model simulations, field measurements, and a conceptual model is shown in Fig. 8(a-d).

MJO Forecast: From the forecasting point of view, the MJO represents a link between the weather and climate. Its relatively long time scale forms a base for extended weather prediction and, therefore, understanding of the MJO became a Holy Grail for the forecasting community. However, in spite of its importance, the MJO presents a formidable forecasting challenge, mostly because of its multiscale nature. The MJO system includes eastward and westward moving tropical disturbances with various spatial and temporal scales that interact with the large-scale "MJO envelope"; the air-sea interaction creates another level of complexity.

An interdisciplinary NRL team participated in an international effort, called Cooperative Indian Ocean Experiment on Intraseasonal Variability (CINDY) / Dynamics of Madden–Julian Oscillation (DYNAMO), directed toward understanding MJO dynamics, with the focus on MJO initiation in the Indian Ocean that appears to be especially difficult to predict. During the CINDY/DYNAMO field campaign (October to December 2011), three MJO episodes were observed, providing a wealth of data for MJO investigation. In this campaign, the NRL air-sea-ocean-wave Coupled Ocean–Atmosphere Mesoscale Prediction System (COAMPS) model was used, the first fully coupled high-resolution model run in real time. The model consists of the atmospheric regional model, ocean model Navy Coastal Ocean Model (NCOM), and wave model Simulating WAves Nearshore (SWAN) with the boundary forcing provided by Navy global models and data assimilation in the atmosphere and in the ocean. The model nested grid setup used for the DYNAMO forecasts, with the cloud resolving nest centered on the DYNAMO observational array, reflected the multiscale nature of the MJO. With this model, combined with the atmospheric and ocean observations collected during the field program, we analyzed the transitions from the suppressed stage to the active stage of the